



2016 DOE OE Energy Storage Program Peer Review

A Power Dense Advanced Power Inverter (API) for Grid Tied Energy Supplies

**Phase I & Phase II SBIR: DOE Energy Storage Program,
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- **Project Team: Create & Dynapower**
- **Motivation for this work**
- **Create's API: Features, Advantages, and Benefits**
- **Summary**

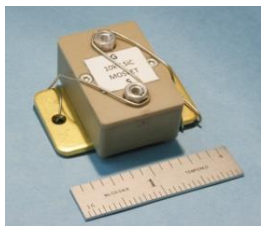
Component Vendors



SiC, 1.2 kV, 500 A



SiC, 1.2 kV, 1,000 A



SiC, 10 kV, 25 A

Create: Value Added Services For Energy Supplies

- Systems engineering
- Design and analysis
- Thermal
- Electrical
- Power systems
- Fabrication
- Testing
- Commercialization

OEM Partners (Upgraded Products)



End Users (Utilities, Military)





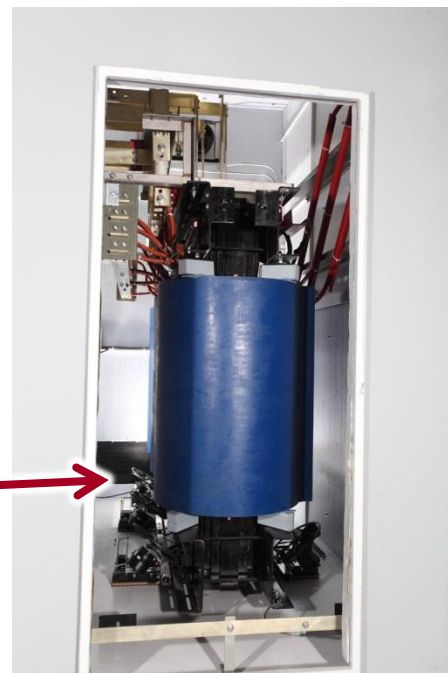
IPS-500
500kW, 480VAC

Liquid-Cooled
Inverter Modules
+ 60Hz Filters

60Hz Transformer



POWERSKID
4.5MW, 13kVAC

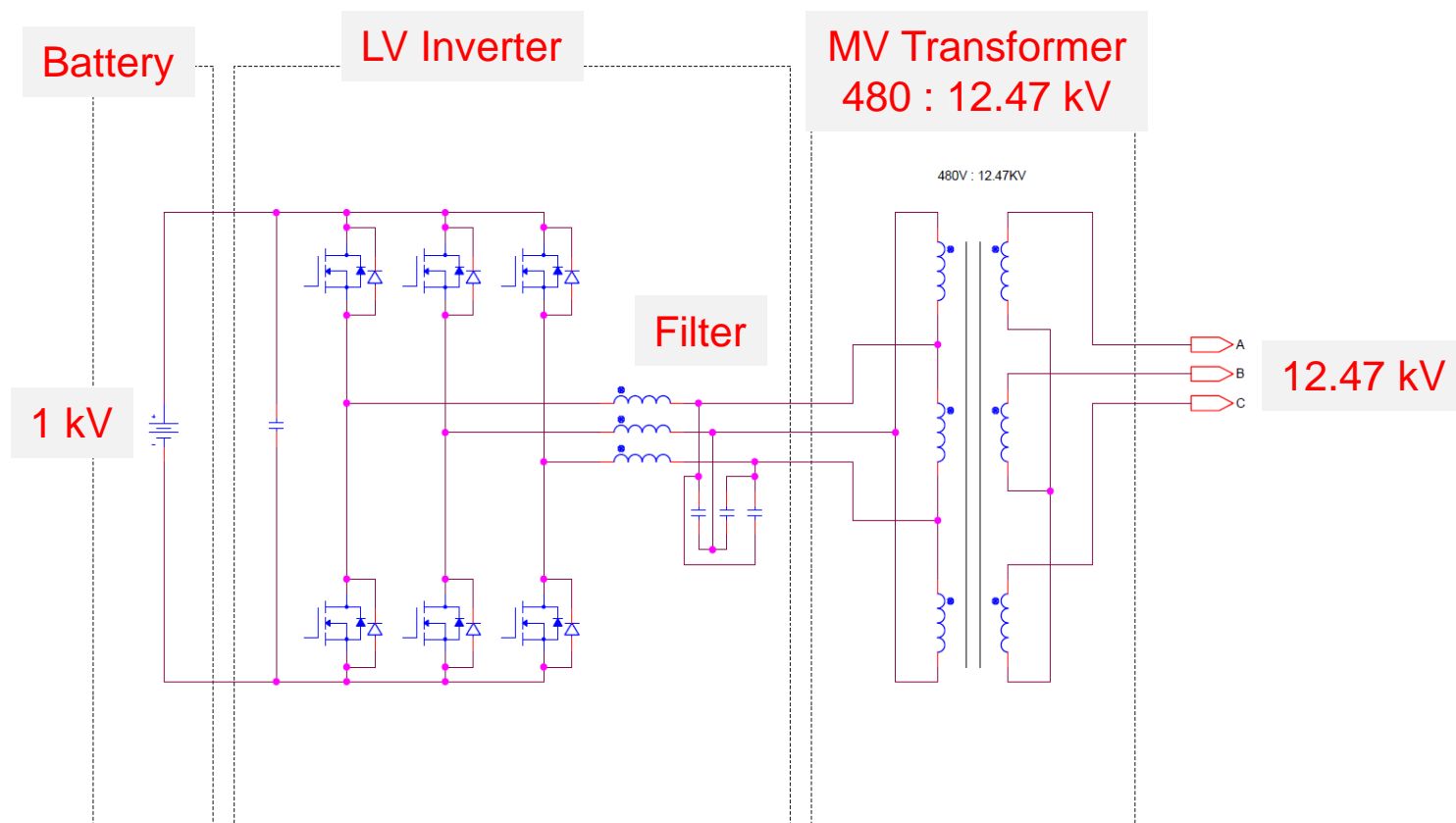


Use SiC WBG technology to improve the value proposition for Grid Tied Energy Supplies:

- **SiC high voltage rating enables direct connection to medium voltage grids (30, 12.47 kV) (*this is the enabling technology*)**
- **Eliminates 60 Hz transformer (*reduces size*)**
- **High operating temperature eliminates liquid cooling (*reduces size, improves reliability*)**
- **Create modular building block for 500 kW to MW+ (*expand markets*)**
- **Achieve >4x power density improvement (*customer benefit*)**
- **Reduce audible noise (*customer benefit*)**

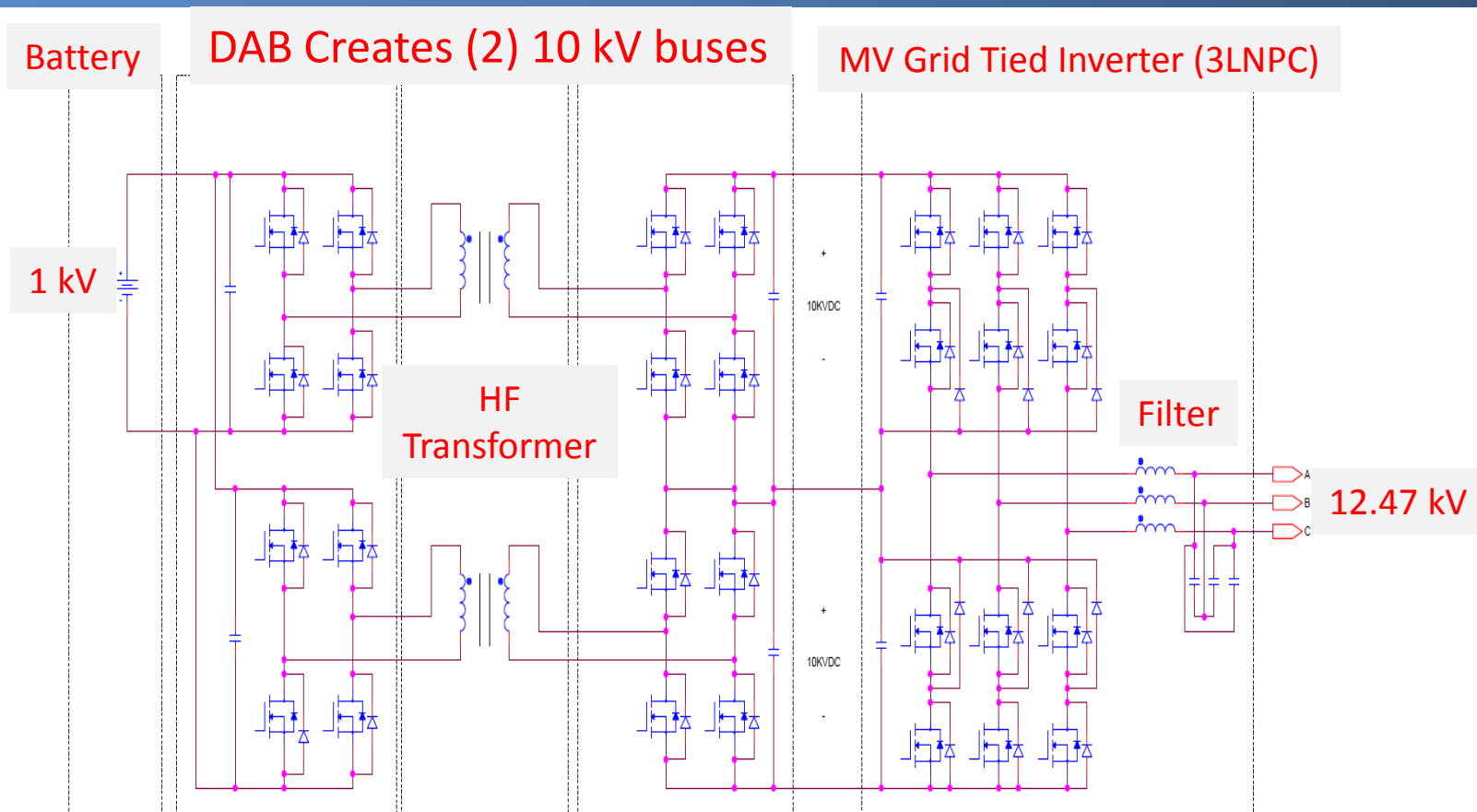
Proposition: SiC devices can improve the value of grid tied energy supplies by reducing size and cost and improving reliability and end user satisfaction.

Typical DC-AC Inverter:



Limitations of this design:

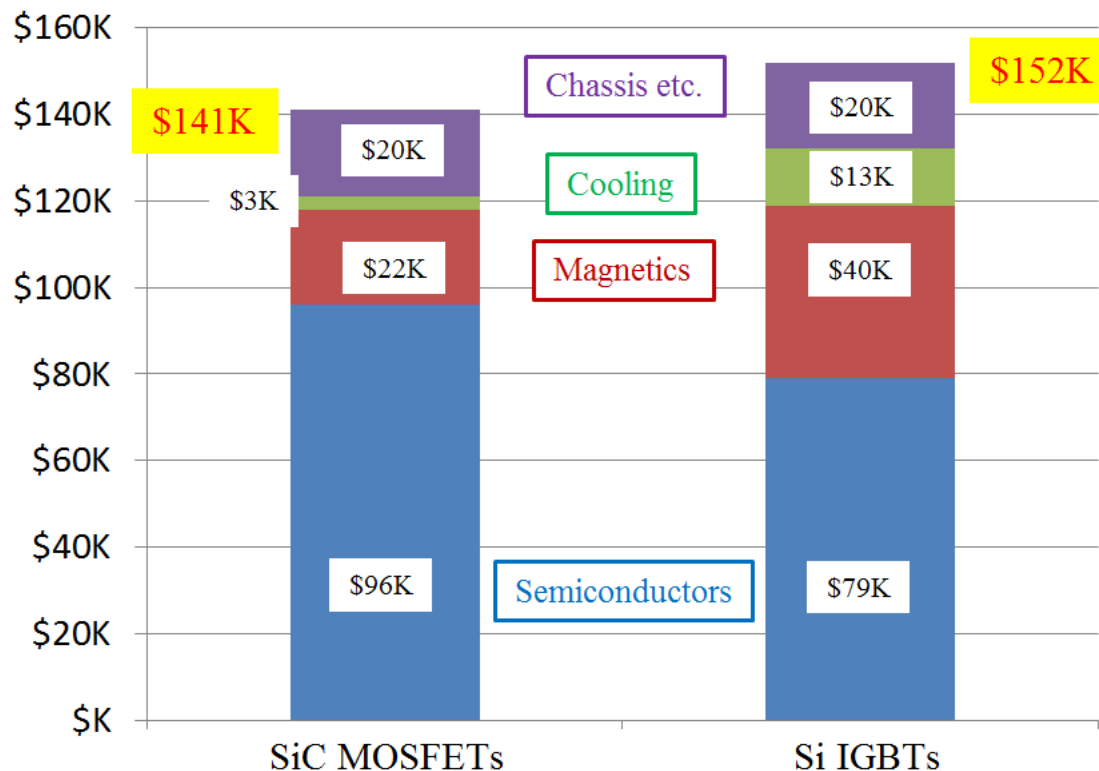
- Requires 480 : 12.47 kV transformer for grid connect.
- Silicon MOSFETs or IGBTs require liquid cooling ($\sim 50^{\circ}\text{C}$).
- Filter is large and also requires liquid cooling.
- 60 Hz transformer emits acoustic noise.



Improvements:

- SiC MOSFETs enable direct grid connection to 12.47 kV.
- 60 Hz transformer replaced with (2) smaller (10X) high frequency transformers.
- Transformer is quieter.
- Liquid cooling is eliminated.
- Filter faces lower current, reduces losses and eliminates liquid cooling.

500 kVA Inverter Cost By Element

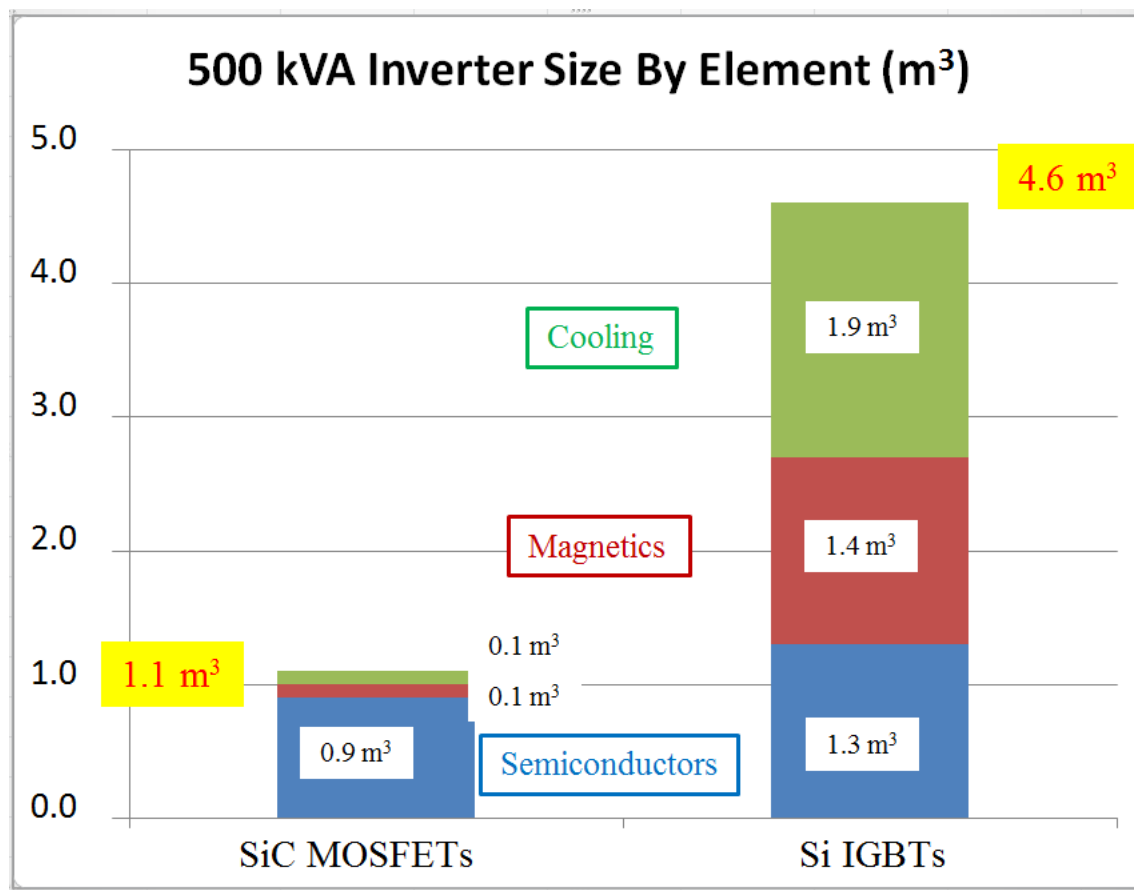


System level per unit material costs are comparable (\$141K vs. \$152K). SiC MOSFET costs are higher than Si IGBTs, but magnetics and cooling costs are lower. **SiC costs are likely to reduce.**

Notes:

- HV SiC MOSFETs require (3) parallel
- HV Si IGBTs require (2) series

Size is 4.3X Smaller: SiC vs. Si



Size of the inverter which uses SiC MOSFETs is much smaller, with 4.3X power density.

Our long-term objective is to provide the API to improve existing products.

Existing 500 kVA Grid Tied Energy Storage Container (Dynapower)

Key:

Eliminate

Add

Incorporate SiC
3LNPC Power
Converter

Eliminate
60 Hz transformer

Change Switchgear
from 600 V to 13 kV

Enables
Renewable Energy
Sources

Eliminate
Liquid Cooling

Reduce or Eliminate
Air Conditioner and Liquid /Air
Heat Exchanger



Nominal Existing Generation System

- 500 kW, 250 kW-hr
- 23 x 8 x 10 ft.
- Includes AC & DC switchgear
- Optional: solar recombiner (600 – 1000 V PV arrays)
- Optional: 4 x 2 x 4 ft. 480:480 transformer
- 3 x 7 x 10 ft. 250 kW-hr Li-ion battery
- Ramp rate control, frequency regulation, VAR support
- Seamless dynamic transfer

Smaller size leads to lower installation costs and simpler logistics. Reliability is better and audible noise is reduced.

Creare's API: Features, Advantages and Benefits

Technical Feature	Competitive Advantage	Customer Benefit
• SiC MOSFET based inverter	• Higher operating temperature and voltage than Si	• Greater power density
• Transformerless, convection cooling	• Smaller size, simpler design, higher reliability	• Lower investment and operating costs
• 12.47 kV, > 1 MW+	• Direct connection to 12.47 kV grid, greater power	• Greater revenue
• Renewables interface	• Enables larger batteries, solar, wind in one container	• Greater source flexibility

- DOE Office of Electricity
- Dr. Imre Gyuk
- Dr. Stan Atcitty

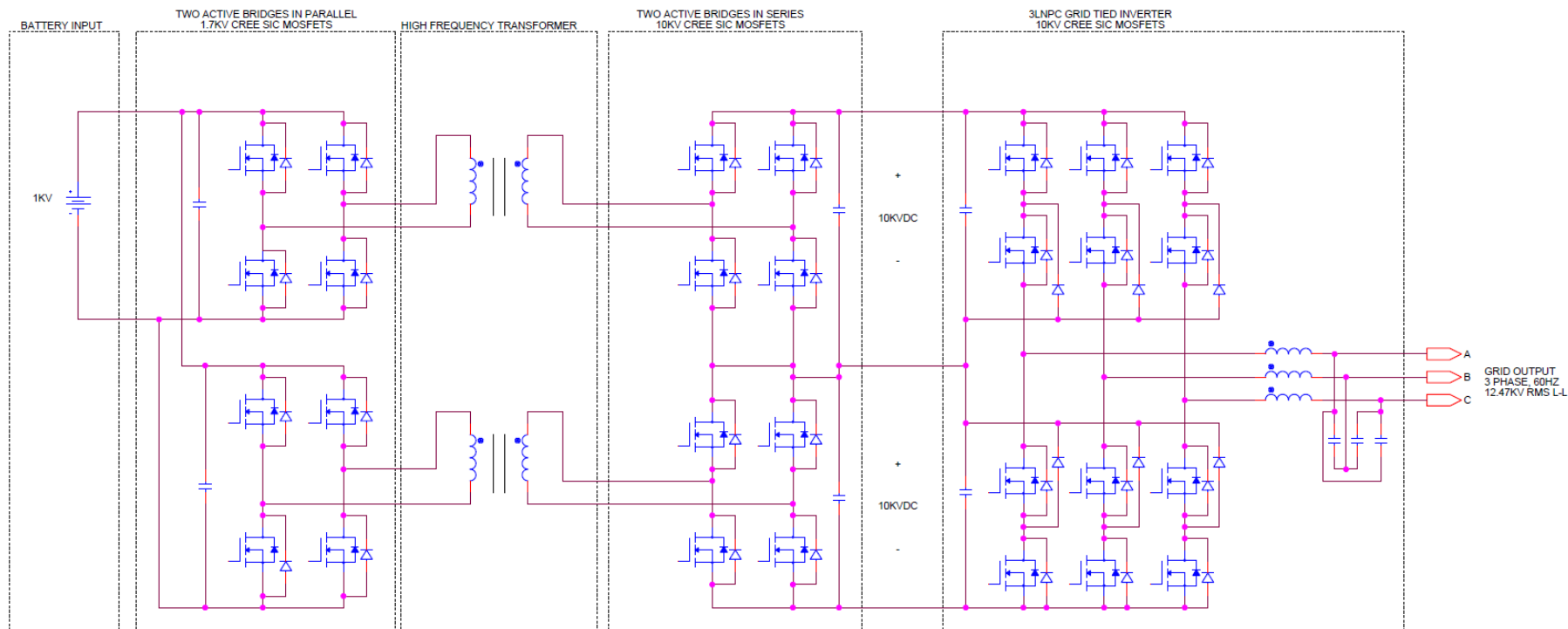
Thank you!

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Creare's API Meets or Exceeds All Objectives		
Parameter	Requirement	Creare's API
Semiconductor Type	Silicon Carbide	Silicon Carbide
Output Voltage (kV)	>12.47	12.47
Output Power (kW)	100	500 (can be combined for MW+ class power)
Power Density Improvement	2X	4.3X
60 Hz Transformer	Eliminate	Eliminated
Cooling	Eliminate liquid cooling	Forced air convection
Power Flow	Bidirectional	Bidirectional

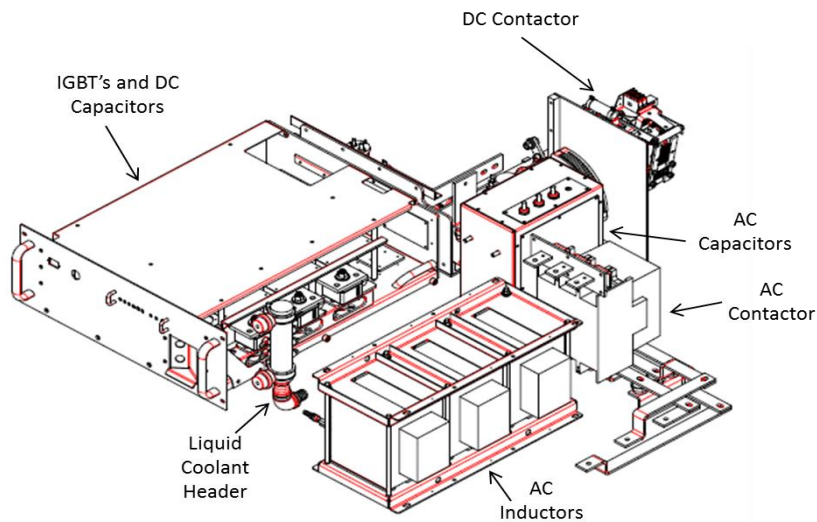


• Pros

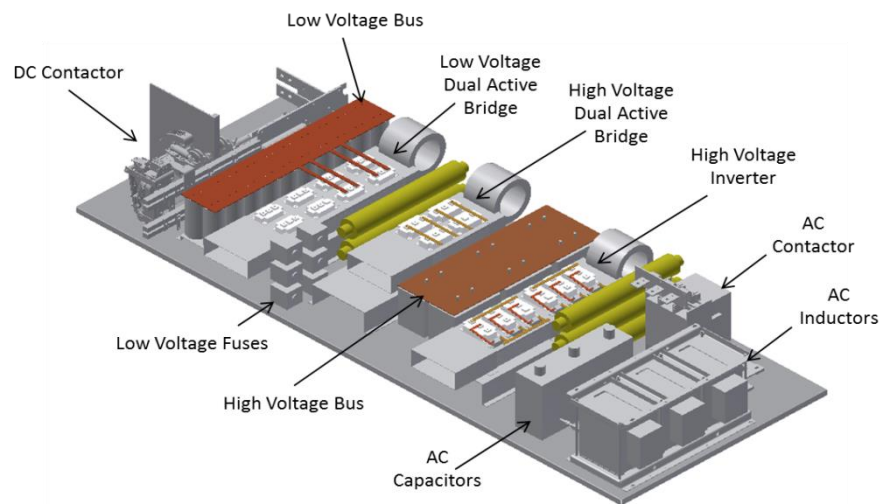
- Reduced stress on primary side.
- Two simpler transformers -- can be on same core if desired. Each has 1/2 the total power.
- Independent DABs can regulate 10 kV DC buses for 3LNPC.

• Cons

- More switches, increased complexity.



Existing Silicon IGBT Power Assembly.
Volume of this power assembly is 1.3 m^3
and total inverter volume is 4.6 m^3 .



Create's SiC API. Volume is 1.1 m^3 and
4.3 times higher power density than the
silicon IGBT design.

Inverter Size Comparison. Create's API is much smaller than existing inverters and does not require a large 60 Hz transformer to achieve 12.47 kV.

Manufacturer	Size (m ³)	Voltage	Power (kW)
Create	1.1	12.47 kV	500
Dynapower (Si)	4.6	480 V	500
Advanced Energy AE500NX	4.8	480 V	500
Solectria SGI500	5.9	208 V	500
SMA America Sunny Central 500	7.0	480 V	500
Satcon Tech. PVS500	9.4	480 V	500

Note that existing inverters have 480 V or 208 V outputs, which requires an additional transformer, such as the Temco medium voltage transformer (480:12.47 kV, three phase 500 KVA, 5.3 m³, \$32,000) to achieve 12.47 kV. This roughly doubles the required size and substantially increases cost.

10 Year Plan for Deploying the API

Development Phase	Time Frame	Objectives/Technical Focus
SBIR Phase I	2015–2016	<ul style="list-style-type: none">• Develop proof-of-concept system• Feasibility testing
SBIR Phase II	2016–2018	<ul style="list-style-type: none">• Full-scale prototype demonstration• Refine business plan• Marketing to existing and new customers• Evaluate peak shaving, energy shifting, ramp rate mitigation, frequency regulation, active VAR management, voltage control
Commercialization	2018–2025	<ul style="list-style-type: none">• Conduct initial demonstrations• Low volume production• Obtain safety certification

Use SiC WBG technology to improve the value proposition for Grid Tied Energy Supplies:

- **Cover the entire conversion process from energy storage to electric utility connection in one container** (*simplifies installation and reduces cost*)
- **SiC high voltage rating enables direct connection to medium voltage grids (30, 12.47 kV)** (*this is the enabling technology*)
- **Eliminates 60 Hz transformer** (*reduces size*)
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Improve the Value Proposition: For utilities and energy consumers who want to reduce the cost and improve the reliability of power delivery while expanding renewable energy capabilities, Creare's Advanced Power Inverter (API) will reduce equipment size and cost, simplify thermal management requirements, and improve harmonic performance.

Advantages

- Higher operating temperature than silicon devices
- Higher operating voltage than silicon
- Enables direct utility connection
- Eliminates 60 Hz transformer
- Eliminates liquid cooling

Disadvantages

- Less mature than silicon devices
- Higher per unit cost than silicon devices

Proposition: SiC devices can improve the value of grid tied energy supplies by reducing size and cost and improving reliability and end user satisfaction.